MICROCOMPUTER-CONTROLLED AC POWER SWITCH CONTROLLER AND DC POWER SUPPLY METHOD AND APPARATUS

RELATED APPLICATIONS

5   This is a Continuation-In-Part Application of co-pending Application Serial

No. 09/251,233 filed February 16, 1999 which is a continuation of U.S. application

filed December 14, 1994

Serial No. 08/358,338, now issued as U.S. Patent No. 5,872,832.

FIELD OF THE INVENTION

This invention relates to AC electric current control systems, such as motor controllers

10   and illumination switches.

BACKGROUND OF THE INVENTION

The connection of AC power controllers with the wiring of buildings is usually

obtainable only with one side of the AC power line. For example, the wire for the

switch circuit from a ceiling or porch light is often connected with the hot side of the

15   AC circuit being the only line switched. Therefore, full line power is not available at

most wall switch locations. As a result of this wiring practice, it is necessary that any

electrical device intended to find popular acceptance as a replacement for a wall-

mounted switch must rely upon merely the power present in the one side of the circuit.

Such a device must be connected in series with the load and the AC power source.

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Also, wall-mounted switch controllers which include dimmers, time-delay devices, emergency flashing devices, variable intensity controllers, and motor controllers are designed as dedicated devices that serve one function and usually are

5   designed where the full line power is available. If not available, then additional wiring is needed.

Weber in U.S. Pat. No. 4,300,090 and Dubot et al in U.S. Pat. No. 4,754, 213 disclose a technique to provide DC power supply by taking the pre-conduction potential which is developed across a thyristor. This potential is derived by fixing the

10   turn-on voltage by zener diodes. The AC power is rectified and filtered to provide low voltage direct current. This requires a thyristor to provide the voltage drop and another thyristor or relay to control the load device current.

Weber noted this deficiency in U.S. Pat. No. 4,878,010 where he uses a slightly different technique in which the thyristor is used for both deriving low voltage

15   DC power and also as the control device. In this patent, Weber derives the power from the zener drop during ON and OFF times to provide the low-voltage DC power. He controls the thyristor by allowing the zener current to the thyristor or diverts the current flow away from the gate of the thyristor to other side of the circuit using a shunting scheme. The turn-on potential of the gate along with the zener voltage sets

20   the low voltage DC power when the thyristor is ON and shunting transistor with the zener voltage sets the low voltage DC power when the thyristor is OFF.

Depending on the thyristor gate voltage, the low voltage DC will be at different levels for the control circuits. Also, Weber discloses in U.S. Pat. No. 4,878,010 a technique to provide AC power control using one side of the AC lines. His technique is limited to charging a capacitor every other half cycle, on only the positive-going AC

5   cycles. Therefore, to maintain the necessary power for the complete cycle, Weber needs to use a much larger capacitor for the storage of the DC power then if one uses every half cycles of AC power. Furthermore, he needs to use thyristors that have sensitive gate control, which are more expensive than typical thyristors. In addition, Weber shows several dedicated configurations for each type of functions, which

10   requires extensive hardware redesign for each function.

Other references shown have circuits which use a microcontroller, but derive their power from charging a large capacitor, batteries, transformers, or are designed to have both AC lines available. Here is the summary of the different schemes which have been proposed to provide power to the control circuitry:

15   In U.S. Patent No. 4,878,010, the device turns ON at a fixed voltage level and provides power during the time the load is powered. However, the device must use a very large capacitor because the device derives power every cycle, and uses a dedicated circuitry. Also, the fixed voltage level limits the usefulness of the device to ON and OFF operations.

20   In U.S. Patent No. 4,754,213, the device uses a thyristor and a large power relay in series. It fixes the ON voltage to a certain level, and uses a dedicated circuitry.

In U.S. Patent No. 4,924,109, the device use the same technique as 4,878,010 and allows for a 30-50% DIM operation.

In U.S. Patent No. 5,481,452, the device has a programmable controller, but derives power from a transformer which is connected to both leads of the AC source,

5   or from a battery when one lead is only available.

In U.S. Patent No. 5, 573,983, the device has a programmable controller, but has a dedicated power supply derived from both AC lines.

In U.S. Patent No. 4,733,138, the device requires two AC power lines for power.

10   In U.S. Patent No. 4,733,138, the device requires a two AC power lines which are coupled by a transformer to derive the DC power supply.

In U.S. Patent No. 4,649,323, the device has a microcontroller and a zero-crossing detector, but uses dedicated DC power supply which is derived from both AC power lines. It requires a choke to operate, and only the switches are wall-mounted.

15   In U.S. Patent No. 5,319,283, the device requires a large capacitor to keep power when the device provides power to the AC load. I t also requires two thyristors for controlling the switching operation.

In U.S. Patent No. 5,811,963, the device charges the large capacitor during the time when the AC load is not being provided power. During the time when the AC

20   load requires power, the device uses the DC power from the stored power in the capacitor. If the power is required continuously, this scheme is not effective.

The disadvantages of the prior art are as follows:

   a.   more and higher cost components;

   b.   limited flexibility for features and functions;

   c.   not a single wire line device, and therefore can not be use in older

5   dwellings.

Accordingly, there has heretofore existed a need for an inexpensive and

effective system for providing an AC power controller who derives its power from

series connection between the AC power source and AC load.

SUMMARY OF INVENTION

The present invention provides a highly versatile microcomputer-controlled switch operating in series with an AC circuit that is installed between an AC load such as a light fixture, and the source for the AC power. This versatile switch controller derives DC power form the AC circuit, which is in series with the AC load and AC power, by stealing a small portion of the AC power every half cycle. This AC power is rectified for each half cycle and is used to maintain a small capacitor charge during the times when controller has turned ON power to the load.

In previous inventions, the capacitor needs to be large enough to maintain DC power for a full cycle or more such as noted in Weber US Pat. No. 4,878,010 or required two thyristors such as US Pat. No. 4,745,213. In both these cases, '010 and '213, the AC voltage used was fixed based on the external connected zeners. The problem with these arrangements is that fixing the voltage where the thyristor turns ON limits the device to ON and OFF operations and does not lend itself to dimming functionality. In this invention, by contrast, the amount of AC voltage can vary or be fixed depending on the microcontroller or circuitry. If one needs to dim the lights or slow down the motor, than the AC voltage would be switch ON at any portion of the AC cycle.

Since this design utilizes an isolation thyristor driver such as a relay or optoisolator driver, the microcontroller can easily be programmed to turn the power to the AC load ON and OFF, similar to if one were to use a controller with a dedicated power supply.

The controller only needs to provide gate current pulse at the beginning of every half-cycle to enable the thyristor. Once the thyristor is provided with a gate current, it turns ON. The thyristor stays ON even without any further current in the gate until the AC voltage goes back to zero.

5   The primary object of the invention is the technique to provide power to the controller by stealing a portion of the AC power at the beginning of the half cycle and to provide the gate current pulse to enable the thyristor. During any portion of the half cycle, the controller can initiate an ON cycle by providing a gate current pulse. Once initiated, the thyristor takes over until the end of the half cycle zero crossing.

10 The controller can maintain an OFF condition by not providing the gate current pulse.

   A further object of this invention is to provide a light level controller, which includes an automated fade function, which gradually fades the light intensity level from a full ON to an OFF condition.

   Another object of this invention is to provide a light controller which the light

15 is turned ON and OFF at long random times from minutes to hours. This simulates that the house is lived in and deters burglars.

   Another object of this invention is to provide a light controller, which has an attention-getting mode that flashes the light from full brightness to dim at a fast, periodic rate. This light controller if installed in the front porch light electrical circuit

20 would help delivery personnel locate the house.

Another object of this invention is a light controller, which dims the light level for a period of minutes and then turns the light OFF. This light controller would be used in a child's bedroom to allow for a quiet time before the light goes off completely.

5   Another object of this invention is a three-position switch where one position selects the power controller, which allows for different modes. The other two positions would be full ON and full OFF.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram showing an of the AC power control circuit in accordance with the present invention;

FIG. 2 is an schematic diagram showing the AC power control circuit of FIG. 1;

5 FIG. 3A is a graphical plot of an AC waveform across the AC power control circuit of FIGs. 1-2, when the unit is in an OFF state;

FIG. 3B is a graphical plot of an AC waveform across the AC power control circuit of FIGs. 1-2, when the unit is in an ON state;

FIG. 4 is a schematic diagram showing an AC power control circuit in accordance

10 with an embodiment of the present invention that derives DC power using half-wave rectification and a resistor;

FIG. 5 is a schematic diagram showing an AC power control circuit in accordance with an embodiment of the present invention that derives DC power using half-wave rectification and a capacitor;

15 FIG. 6 is a schematic diagram showing an AC power control circuit in accordance with an embodiment of the present invention that uses a relay for the thyristor driver;

FIG. 7 is a schematic diagram showing an AC power control circuit in accordance with an embodiment of the present invention that uses an optoisolator for the thyristor driver and larger value for resistor R2;

20 FIG. 8 is a schematic diagram showing an AC power control circuit in accordance with an embodiment of the present invention that uses a zero crossing detector to determine when to when to trigger the thyristor driver;

FIG. 9 is a block diagram showing an AC power control circuit in accordance with an embodiment of the present invention which incorporates a microcontroller having the capability of receiving inputs from different sensors and driving different AC loads;

FIG. 10 is a schematic showing the AC power control circuit of FIG. 9 with zero-crossing detector and mode selection functions;

FIG. 11A is a graphical plot of an AC voltage waveform across the AC power control circuit of FIG. 10 when the device is OFF state;

FIG. 11B is a graphical plot of an AC voltage waveform across the AC power control circuit of FIG. 10 when the device is ON state;

FIG. 11C is a graphical plot of an AC voltage waveform across the AC power control circuit of FIG. 10 when the device is ON state for only half of the AC cycle;

FIG. 11D is a graphical plot of an AC voltage waveform across the AC power control circuit of FIG. 10 when the device is ON state for only a quarter of the AC cycle;

FIG. 12 is a graphical flowchart of the program of the device in FIG. 10 for continuous dimming an AC light from ON to OFF over a period of time;

FIG. 13 is a graphical flowchart of the program of the device in FIG. 10 for randomly turning an AC load ON and OFF over a period of minutes and hours;

FIG. 14 is a graphical flowchart of the program of the device in FIG. 10 for flashing an AC light between ON and DIM;

FIG. 15 is a graphical flowchart of the program of the device in FIG. 10 for dimming the lights for period of time and then turning the lights to an OFF state;

FIG. 16 is a graphical flowchart of the program of the device in FIG. 10 for randomly

turning the light to an ON state, an OFF state, and a DIM state at a high flash rate;

FIG. 17 is a graphical flowchart of the program of the device in FIG. 10 for turning

the lights to an OFF state after a period of time;

5   FIG. 18 is a graphical flowchart of the program of the device in FIG. 10 for flashing

the light to ON and OFF states, and sounding a beeper;

FIG. 19 is a graphical flowchart of the program of the device in FIG. 10 for turning

the light to an ON state for period of time and then to a DIM state thereafter;

FIG. 20 is a graphical flowchart of the program of the device in FIG. 10 for dimming

10   the light;

FIG. 21 is a block diagram showing a three-position switch combined with the AC

power control circuit of FIGs 1-2;

FIG. 22 is a perspective view showing an electrical switch box with the three-position

switch and AC power control circuit of FIG. 21 housed therein;

15   FIG. 23 is a perspective view showing an AC electrical system with the AC power

control switch of FIG. 22 in series with the light; and

FIG. 24 is a perspective view showing an AC electrical system with AC power control

switch of FIG. 22 with reverse connection to the AC power and AC load.

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DESCRIPTION OF INVENTION

<u>a. OVERVIEW</u>

FIG. 1 shows a block diagram schematic of the AC power control circuit 38 in

which AC power from AC source 18a and 18b is applied to load 14 under control of

5   series power control circuit 38. The AC power control circuit 38 includes a thyristor

36, the power network 20, a thyristor driver 34, and the control circuit 30. The power

network 20 provides low voltage through lines 24 and 26 continuously to operate the

control circuit 30 and the necessary drive current pulse when needed by the thyristor

driver 34 via lines 22 and 25. The thyristor driver 34 provides the necessary gate

10   current pulse to turn the thyristor 36 ON.

A thyristor 36 is a semiconductor power switch that allows high current AC or

DC to flow when trigger by a gate current pulse. Two types of thyristors are SCRs

(Silicon-Controlled Rectifiers), and TRIACs (TRIode AC switches).

The operation, principle components, and exemplary applications for the

15   invention are described in greater detail under the appropriate subheadings below.

<u>b. CYCLE-STEALING</u>

FIG. 2 shows an electrical schematic of one version of the AC power control

circuit 38 illustrated in FIG. 1. Here, the control circuit uses a microcontroller 31.

Each block of FIG. 1 is represented by electronic components. In this circuitry, the

20   power network 20 provides the continuous power to the microcontroller 31 shown as

a Microchip PIC 12C508A. The circuit includes R1 and C1, which minimizes the

current and voltage to acceptable level. Diodes D1, D2, D3, and D4 converts AC

power to DC power. Diode D6 is a zener diode, which keeps the voltage level on

lines 24 and 26 to an acceptable level for the microcontroller 31.

Capacitor C2 maintains the current to the microcontroller 31during the times when the
AC power is not provided. The thyristor driver circuitry includes resistor R2, diode
D5, an optoisolator triac driver 40 shown as a Motorola MC3011, and resistor R3.
To enable the triac driver, the microcontroller 31 allows a minimum current pulse to

5   flow through line 25. The output lines 27 and 28 of the triac driver 40 closes the path
from resistor R3 to the gate of the thyristor 36. This provides a gate current pulse to
the thyristor 36, which causes the thyristor to conduct and be in an ON state. Once
the thyristor 36 is ON, there will be no more current flowing to the control circuitry
via lines 16a, R1, and C1. The thyristor 36 stays ON until the AC voltage across

10   terminals 16a and 16b goes to zero, which happens every half cycle.

The minimum current pulse to trigger the thyristor driver which triggers the
thyristor is provided by the power network circuitry via R1, C1, the diodes D1-D4,
resistor R2, and diode D5 through the output line 25 of the microcontroller 31.
Resistor R1, capacitor C1 and resistor R2 limit the current to the thyristor driver 40.

15   D5 provides a minimum level of voltage to line 24 so that the microcontroller 31 has
sufficient DC power during the time when it output drives the thyristor driver 40
continuously ON. Diode D5 can be eliminated in configurations where the
microcontroller monitors the zero crossings and provides the necessary gate current
pulse for the minimum duration needed to trigger the thyristor or when R2 is high

20   enough value that the current draw from C2 is minimal.

FIGS. 3A and 3B illustrate the AC waveforms appearing across lines 16a and 16b of FIG. 2 during an ON and OFF actuation. In the OFF situation, the thyristor is not provided with any gate current pulses and the voltage across lines 16a and 16b is the same as the applied waveform. During this time, there is sufficient current supply

5   for the internal circuitry whenever the voltage is above that indicated at 294. The internal voltage on lines 24 and 26 is clamped by diode D6 in FIG. 2 to provide an acceptable source of DC power for control circuitry 30.

In a fully ON situation, the thyristor is enabled when the instantaneous voltage indicated at 300 across the thyristor 36 provides enough power indicated at 304 to the

10   internal circuitry both for the microcontroller and for enabling the driver 40 to provide the gate current pulse. FIG. 3B shows the voltage across lines 16a and 16b when the thyristor is in an ON state. At the beginning of each AC half cycle, a small portion of the AC power is "stolen" and used by the internal circuitry, hence the term "cycle-stealing" as used here. When the voltage reaches a level to supply the necessary

15   current to trigger the thyristor driver and therefore the thyristor, the thyristor is turned ON providing a low impedance path for the AC current. This low impedance condition provides power to the AC load 14 through the thyristor 36.

From FIG. 1, the invention utilizes the AC power source from a wire lead 18a to control the AC load 14. The invention is connected in series with the AC power

20   source 18a and the load 14 via first and second leads, 16a and 16b.

The thyristor 36 is in series with the leads, 16a and 16b, and controls the flow of AC current to the load 14 in response to activation of the thyristor 36 by a gate current pulse. The gate current pulse is produced by the driver 34.

The driver 34 is selectively controlled by the control circuitry 30. The control circuitry 30 obtains its DC power from the power converter network 20. The power converter network 20 is coupled between first and second leads, 16a and 16b. The power converter network 20 adapts or steals a portion of the AC current at the beginning of each half cycle of the AC current and converts the AC current into a source of DC current for the control circuitry 30.

c. POWER NETWORK

Some examples of different power networks that will supply DC power to the cycle-stealing device include the following:

FIG. 4 shows a second embodiment, where the power conversion network includes resistor R1 and diode D1 instead of R1, C1, and diodes D1-D4. Here, the resistor R1 has a larger power rating to handle the current flow needed for the microcontroller 31 and thyristor driver 40. In order to minimize the current, this circuit uses a thyristor driver 40 with a more sensitive internal LED such as the Motorola MC3012. Diode D1 only provides power on every positive-going AC cycle.

FIG. 5 shows third embodiment where the electrical circuit uses a capacitor C1 and a smaller value for R1 to provide the needed power. Diode D2 is needed for allowing the AC voltage to charge and discharge capacitor C1. The DC power is derived from the AC power only on positive-going AC cycles.

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d. THYRISTOR DRIVER

FIG. 6 illustrates another embodiment of the device using a relay 41such as 12 VDC reed relay, Radio-Shack No. 275-233, instead of an optoisolator driver 40 in the circuitry. D5 is not needed because R2 and the resistance of the relay coil is large enough to minimize loading of the power network.

FIG. 7 illustrates another embodiment of the device using an optoisolator driver 40 with only a higher value resistor R2. With this circuitry, the AC voltage across leads 16a and 16b will be much higher to produce the necessary drive current for the optoisolator driver 40. To minimize the drive current, a more sensitive optoisolator driver such as Motorola MC3012 would be used.

FIG. 8 illustrates another embodiment of the device using the a smaller value resistor R2 but includes another resistor R4 to detect the zero crossing of the AC voltage. The microcontroller 31 is programmed to pulse line 25 long enough to provide sufficient gate current pulse to trigger the triac T1. With this circuitry, the AC voltage across leads 16a and 16b will significant smaller than in circuit of FIG. 8. With smaller AC voltage waveform, a lower EMI (ElectroMagnetic Interference) can be achieved.

e. CONTROL CIRCUITRY

FIG. 9 shows different embodiments of the control circuitry 30 of FIG. 1.

FIG. 9 shows the microcontroller 31 with various inputs from different sensors such as

5   a motion sensor 70, temperature sensor 76, smoke detector sensor 72, burglar switch

74, mode selection switches 78, and a zero crossing detector 50.

Also, FIG. 9 shows the microcontroller 31 driving a speaker 80 or LED 82 from its

outputs in addition to driving the thyristor driver 34. The AC power controller 40 can

drive lights 60, resistive loads 62, and motors 64. The microcontroller can be

10   programmed to turn on the light when it detects motion in the room or turn on the

heater motor when the temperature is low.

FIG. 10 shows an electrical circuit similar to FIG. 2 but with zero-crossing

detector circuitry, a speaker B1 and mode selection 33, 35, and 37. The zero-crossing

detector circuitry uses resistor R4 to limit the current into the microcontroller 31. The

15   microcontroller 31 contains internal diodes, which limits the AC voltage to

microcontroller supply voltage line 24 and supply return line 26. Since the zero

crossings are detected, the microcontroller only needs to turn on the driver for a short

time to enable the gate current pulse. This allows for the elimination of diode D5.

FIGS. 11A, 11B, 11C, and 11D is a graphical plot of variable AC voltage

20   triggered at different points on the AC cycle. The device is triggered by providing the

gate current pulse after detecting the zero crossing. FIG. 11A shows when the zero

crossing detected at time t(0). FIG. 11B illustrates the voltage across the thyristor

when the AC load is powered at time t(1) and t(2) after stealing a portion to power the

microcontroller 31 and providing the gate current pulse. In FIG. 11B, the AC load,

such as a light, would be ON. FIG. 11C illustrates that the load is not powered until

time t(2) and only a half cycle of power is applied to the load. If the AC load were a

5   light, the light would dim to about half brightness. FIG. 11D shows that the load is

not powered until time t(3) and only a portion of the half cycle is applied to the load.

In FIG. 11D, the AC load would only received portion of the AC power. The

microcontroller can be programmed to provide power to the load at any time for any

duration.

10   f. MICROCONTROLLER PROGRAM

FIG. 12 shows the flowchart for the program implemented in the

microcontroller 31. FIG. 10 is the electrical circuitry and FIG. 11 illustrates the

waveform of the operation. With the program illustrated in FIG. 12, a continuous

dimming capability from 100 % to OFF condition over any time period is achieved.

15   The flowchart in FIG. 12 shows three timers. The first timer sets the time

period when the light is fully ON to when the light is fully OFF such as thirty minutes.

The second timer sets the time period for how long the light will be in each dimming

position, such as eight seconds, for example. The third timer sets the time period from

the zero crossing until the light is turned ON such as two milliseconds for one

20   dimming setting. This example of two milliseconds can be represented of the third

timer at time t(1) of the cycle. When the third timer is at t(3) of the cycle, the AC load

would only be ON for about 25% of the time This third timer is varied over the first

timer's period from turning the light ON to full brightness to turning the light ON at

the end of the full cycle is completed which is 1/60 second for a 60 Hz AC power

source. Each dimming setting will be ON for the duration of second timer.

Also, the microcontroller 31 is programmable for several other functions. FIG.

5   13 shows the flowchart of a program which turns the light 60 ON and OFF randomly

between time periods in minutes or hours. This simulates that the house is occupied

and deters burglars from breaking into the home. FIG. 14 illustrates the program for

flashing the light 60 between ON at full brightness and dim at a visually discernable

rate, such as four seconds. If installed in the circuit for the porch light, this would

10   bring attention to the house so that the pizza or other delivery services could easily

locate the house. FIG. 15 illustrates the program for turning the lights to dim for a

period of time such as twenty minutes and then OFF. This feature would allow

parents to keep the light ON low for their children until they fell asleep and then

automatically turn OFF. FIG. 16 illustrates a program to randomly turn the light 60

15   ON, OFF, and DIM at a high rate in seconds. This flickering effect would provide a

party-type atmosphere. FIG. 17 illustrates a program to turn the lights OFF after a

pre-set period of time such as ten minutes. FIG. 18 illustrates a program to turn the

lights ON and OFF at a relatively high rate, such as a second, and which sounds a

beeper B1 while it is in an OFF cycle. If used on the front porch light would allow

20   emergency response personnel to locate the home more quickly and alert the

occupants that the device is functioning by the sound. FIG. 19 illustrates the program

for turning the light 60 on for a period of time such as twenty minutes and than dim

thereafter. This would be used on lights to save energy, but not eliminate the lighting.

FIG. 20 illustrates the program where light 60 is turned ON every half cycle thereby

providing a dimming function.

g. MOUNTING SCHEMES

5   Mounting the AC power controller 38 with a three-position switch 102

provides three levels of operation as shown in FIG. 21. The apparatus 100 is

connected in series with the light 60 and AC power lines 18a and 18b. The three

levels of operation are the ON position 80, the OFF position 82, and the MODE

position 84. In the MODE position 84, the AC power controller 38 operates the light

10   in accordance with its programmed operation. FIG. 22 shows the three-position

switch and the AC power controller 38 in an electrical box 110. Lines 19 and 16b

connect to the light 60 and the AC power. FIG. 23 and FIG. 24 show the connections

to the electrical circuit. Either line 19 or 16b can be connected to the AC load or AC

power.

15   The invention may be embodied in other specific forms without departing from

the spirit or essential characteristics thereof. The present embodiments are therefore

to be considered in all respects as illustrative and not restrictive, the scope of the

invention being indicated by the appended claims rather than the foregoing description.